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A study of the electrodeionization process — high-purity water production with a RO/EDI system

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Abstract

An electrodeionization post-reverse osmosis (RO/EDI) system was developed for the continuous production of high-purity water without the use of chemicals. The study was carried out with a laboratory pilot. The ion-exchange membrane stack has eight cell-pairs of which four dilute compartments were filled with mixed-bed ion-exchange resins. The feed is tap water with a conductivity of about 400 μs/cm, and the RO permeate with a conductivity less than 20 μs/cm. The EDI was achieved with a productivity of 20 l/h and a resistivity of 12–18 MΩ-cm. In addition, the V-I and pH-I characteristics of the EDI process were studied. It indicates that there are differences between the ED and the EDI in the concentration polarization.

Keywords: Electrodeionization (EDI); Hybrid process; High-pure water; Ion-exchange membrane; Desalination

1. Introduction

Electrodeionization (EDI), also known as continuous deionization (CDI), is a novel hybrid separation process combining ion-exchange resins with ion-exchange membranes in one unit. The EDI process was discovered in the 1950s [1–3] in a laboratory, and the first commercial apparatus for the production of high-purity water was available in 1987 [4]. Now EDI technology has been discovered and will have numerous applications in many engineering fields.

The principle diagram is shown in Fig. 1. The dilute compartment is filled with mixed-bed ion-exchange resins which enhance the transport to the membranes under the force of a direct current. The ion transport is almost entire through the ion-exchange resins and is not affected through the water. Under certain conditions, a water-splitting reaction occurs in the dilute chamber and then the relatively high concentrations of H^+ and OH^- are able continuously to regenerate

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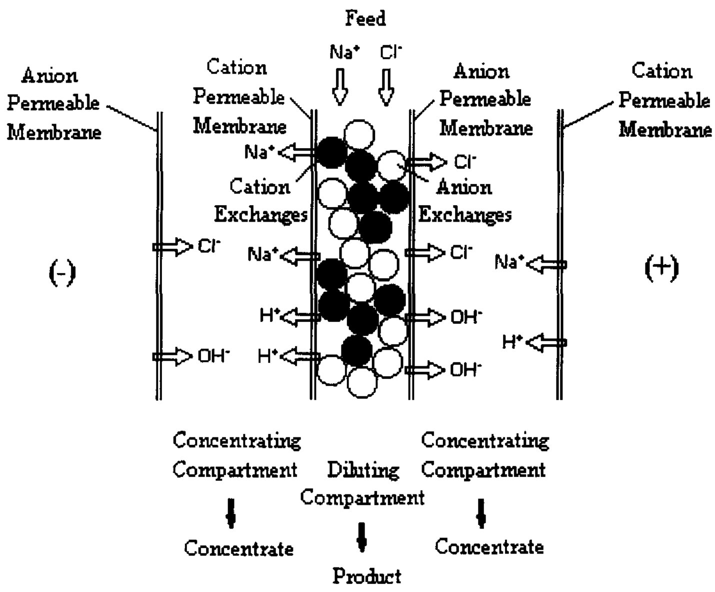

Fig. 1. Diagram of the EDI process.

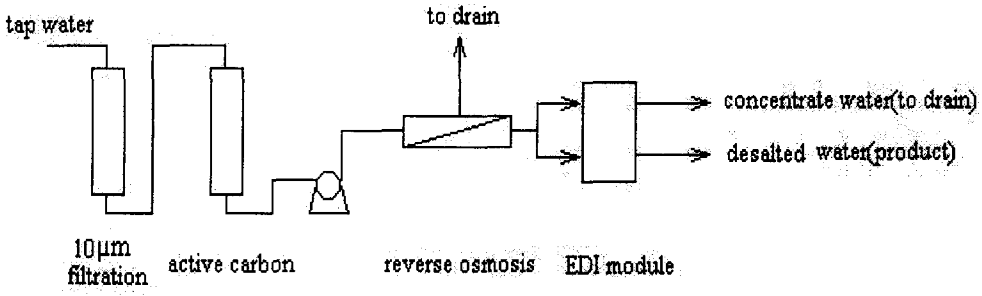

Fig. 2. Flow diagram of the RO/EDI system.

the resins. With unique "electro-regeneration", the EDI unit can be considered as a mixed-bed ion-exchange column with continuous regeneration, and therefore is capable of deep deionization. Comparing with electrodialysis and ion-exchange, respectively, EDI has had superior results in water desalination.

2. Experimental

The flow diagram of the RO/EDI system used is shown in Fig. 2. The processes for production of high-purity water from tap water consist of pretreatment (with 10 μm-filtration and active carbon), RO and EDI.

The pretreatment unit provides good safety for the downstream steps, and the RO unit provides permeate that is demineralized more than 95% (lower than 20 μs/cm) and be directly fed into the EDI stage. The EDI module has four dilute compartments and five concentrate compartments without electrode compartment. Each chamber is 30 cm in length and 10 cm in width. The ion-exchange membrane has an effective area of

158 cm^2 each. The flow rates of desalted water and concentrate of the EDI are 20 $L\cdot h^{-1}$ and 2 $L\cdot h^{-1}$, respectively.

3. Results and discussion

3.1. V-I characteristics

The voltage-current curve of the EDI stack in our experiment is shown in Fig. 3. As can be seen, in the whole range of the experiment, the electrical current of the stack increases more rapidly than the voltage, and there is no polarization point (limiting current) on the voltage-current curve as same as that of the ED process. The reason is that even at applied low voltage, a significant amount of H^+ and OH^- ions are produced in the dilute compartments. The higher the applied voltage, the more H^+ and OH^- are produced.

3.2. pH-I characteristic

Fig. 4 shows the influence of current on pH of desalted water and concentrate. Since the H^+ and OH^- produced in the dilute compartment can regenerate the resins electrochemically, the pH of the desalted water always remains stable while the current continuously increases. The pH-I curve of the concentrate indicated that, in the EDI process, the limiting current at which water decomposition occurs within the boundary layer at the cation-exchange membrane interface is much lower than that of the anion-exchange membrane, which is also much different than that of a typical ED process. Further study has indicated that there exist many differences in the concentration polarization between EDI and ED.

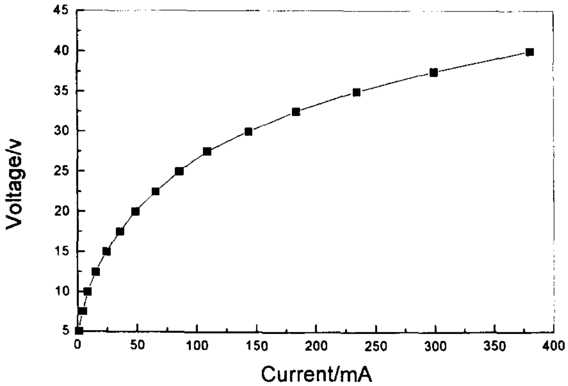

Fig. 3. V-I characteristic of the EDI process.

3.3. Quality of product water

The EDI module performs a polishing function when treat RO permeate. The results of 100 h of operation at constant applied voltage of 20 V and steady RO feed quality (14–18 μs/cm) are shown in Fig. 5. The EDI treatment gives a rejection of more than 99%, which cannot be achieved by a conventional ED process.

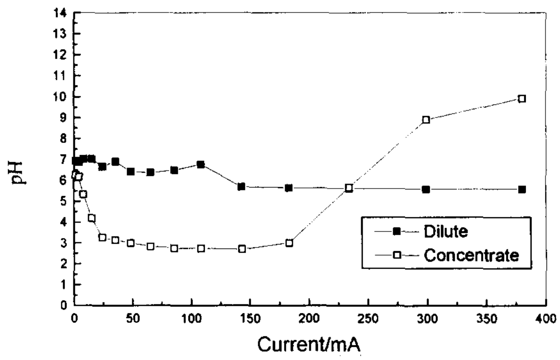

Fig. 4. pH-I characteristic of the EDI process.

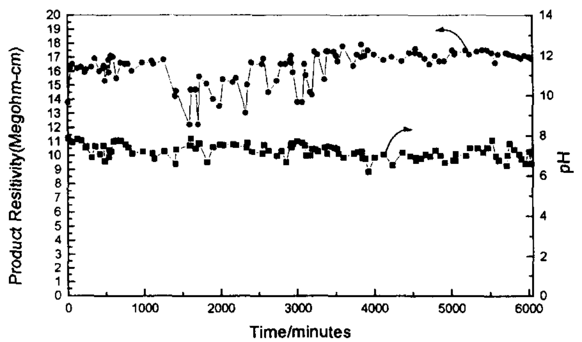

Fig. 5. Stability of the water quality production.

The resistivity of the production water is between 12–18 MΩ·cm. During most of the operation, the product quality is better than 15 MΩ·cm. Sixty hours after the start-up, the product resistivity is steady between 17.0± 0.7 MΩ·cm. The pH of the desalted water remains more or less stable at 7.0±0.8.

References

[1] R. Kunin and R.J. Myers, Ion Exchange Resins, Wiley, New York, 1950, p. 109.
[2] W.R. Walters, D.W. Weiser and L.J. Marek, Industrial Engng Chem., 47(1) (1955) 61.